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MUSHROOM PESTS AND THEIR CONTROL

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INTRODUCTION

The great increase in both commercial and amateur mushroom growing in the United States during the last 30 years has brought increasingly to the attention of the growers the fact that cultivated mushrooms are subject to serious loss from insects, mites, fungus weeds, and diseases. This circular deals principally with the insects and mites that attack mushrooms and with their control. Especially in such districts as southeastern Pennsylvania, which produces more than 50 percent of the mushrooms grown in the United States, where some mushrooms are grown at all seasons of the year, and in which the industry is greatly concentrated, insect and mite pests are a constant menace.

Mushroom flies (Sciaridae), manure flies (Phoridae), the mushroom mite, and the long-legged mite are the most important pests of cultivated mushrooms in the United States. In addition to these, however, there are several other pests of lesser importance.

Extensive experiments have demonstrated that the control of mushroom insects and mites, once they have become established in the houses,[1] is very difficult, owing to the extreme sensitiveness of the mushrooms to chemicals, and because the chemicals that have so far been in use and are known to be safe to use do not readily penetrate into the beds. Nevertheless, by means of sanitation, proper composting and heating, and fumigation, these pests can be reduced in numbers or entirely eliminated before the beds are spawned, and largely prevented from entering the houses thereafter.

[1] The general term "mushroom house", as used in this circular, refers to any location where mushrooms are grown.

This circular is designed to acquaint the grower with the principal mite and insect pests of mushrooms, their life histories in a general way, and the steps to be taken to prevent them from damaging the crop.

IMPORTANCE OF PROPER COMPOSTING FOR CONTROL OF MUSHROOM PESTS

Proper composting of manure for mushroom culture is an important factor in the control of mushroom pests. Composting is best done upon a concrete floor. This prevents the entrance into the manure of many pests from the ground and, if there is a gutter around the edge that may be kept filled with water, many fly maggots will be trapped and drowned therein as they leave the manure. Whether composting upon concrete or upon the ground, the composting floor should be well scraped and cleaned, drenched with a solution of 1 gallon of formaldehyde to 50 gallons of water, and allowed to air for from 2 to 4 days before the manure is placed upon it.

Upon receipt, the manure should be well forked over, all lumps and cakes broken up, and straw added if necessary. The temperatures within the heap, except at ground level, are too high to allow insects and mites to survive, but both mites and insects can develop in the cooler outside layer of from 3 to 6 inches. The heap should therefore be kept well ricked up during the composting so as to expose as little surface as possible to attack. Along the ground level the temperatures are often under 100° F., oxygen is practically lacking, and the carbon dioxide concentration is very high. Under these conditions the manure may remain uncomposted until it is turned and thrown to the outside of the heap. This combination of low oxygen and high carbon dioxide concentration, while perhaps causing pests to become inactive, probably kills very few of them and does not prevent the entrance of others from the soil.

One of the principal difficulties confronting the amateur who contemplates growing mushrooms in small quantities in a cellar, barn, or other structure is that of properly composting small quantities of manure. This procedure is intimately related to the control of mushroom pests. Severe infestations of flies, mites, and springtails may result from the carriage of eggs and larvae into the beds with the compost, unless the compost is in proper condition to go through a good secondary fermentation or "heat" in the beds, to raise the temperature to a point where insects and mites are killed. A half ton of manure of average quality is sufficient for from 35 to 45 square feet of mushroom bed, and it is extremely difficult to obtain proper composting of less than this quantity. One of the advantages of growing mushrooms upon a small scale is the practicability of screening the small compost heaps with cheesecloth to exclude insects; another is the ease with which a small composting floor of concrete or of 2- by 12-inch planks may be constructed, thus preventing the entrance of insects from the soil.

PRECAUTIONS TO BE OBSERVED IN PREPARATION OF THE MUSHROOM HOUSE OR CELLAR

Mushrooms are grown commercially in specially constructed houses, in various old buildings made over for the purpose, and in caves and mine galleries. Amateur growers ordinarily make use of basements or sheds. In buildings, raised beds in tiers are generally used. A space of from 6 inches to 1 foot should be left between the floor and the bottom of the lowest bed. This permits the bottom bed to heat better and facilitates proper cleaning of the floor. It also allows space for the circulation of fumigants, which is highly essential in pest control. In caves and mine galleries the mushroom beds are usually built upon the floor and are referred to as "ground beds." They cannot be heated or fumigated properly and are therefore very difficult to free from insect pests once these have become established. Special care should be exercised to prevent the entrance of pests into such places. Small crops grown by amateurs in cellars and other suitable places about their homes are particularly susceptible to insect attack, as these places are seldom capable of being properly fumigated. The room where mushrooms are to be grown should be separated from the rest of the building by partitions insulated with sawdust or cork if possible, but in any case made as tight as possible with building paper or other material.

Between crops, the house, cellar, or other growing space should be cleaned out thoroughly and the bedboards and supports scraped, brushed, and washed.

SPRAYING OF THE HOUSE

About 2 weeks before it is filled with compost the room should be sprayed to get rid of any insects, mites, or disease fungi that might be left over from the preceding crop. Several sprays have been in use for this purpose, including the following:

(1) Copper sulphate, at the rate of 6 pounds to 50 gallons of water.

(2) Calcium hypochlorite, at the rate of 10 ounces to 50 gallons of water.

(2) Mercuric chloride, at the rate of 8 standard tablets to the gallon of water or one-half pound of crystals to 50 gallons of water.

(4) Formaldehyde, at the rate of 2 gallons to 50 gallons of water.

(5) Lime-sulphur, at the rate of 1 gallon of boiled lime-sulphur to 10 gallons of water.

The best spray for mushroom houses is the boiled lime-sulphur, since this spray is a fungicide and bactericide as well as an insecticide, which most of the materials mentioned above are not.

In caves, and in some mine galleries where there is no danger of setting the wooden bracing afire, flame throwers have been successfully substituted for sprays. The beds are first cleaned out, all loose spent compost is swept up, and the flame is played over the walls, ceiling, and floor, raising the temperature of these high enough to preclude any possibility of insect survival.

FUMIGATION OR STERILIZATION OF THE HOUSE BEFORE FILLING

Immediately before the compost is brought in, the house should, if possible, be fumigated with either formaldehyde or sulphur, or it

should be sterilized by heating. In caves, owing to poor ventilation and ground beds, and in cellars, owing to the possibility of the gas escaping, it is not always possible to do this. Formaldehyde is a good germicide and fungicide, but the gas from burning sulphur is about as good, and is also a useful insecticide, and is specific for mites. Before the house or room is fumigated or sterilized it should be made as airtight as possible by tightly closing all ventilators and other openings and by pasting paper or plastering mud over all cracks.

In cellars and other places close to dwellings it is not advisable to use sulphur or other materials as fumigants, unless such places can be sealed tightly enough to prevent all fumes from escaping. Sulphur should not be used where there is any possibility of the fumes reaching mushroom beds in production, as the growing mushrooms will be damaged.

FORMALDEHYDE FUMIGATION

Formaldehyde is used at the rate of 1 quart to 1,000 cubic feet of the air space to be fumigated. One pound of permanganate of potash is used to the quart of formaldehyde. Crocks, wooden buckets, or other containers of about 10-gallon capacity are needed, each of which will take care of 1 gallon of formaldehyde. Four pounds of the permanganate is placed in each of these, and a gallon of the formaldehyde in a wide-mouthed container beside it. Starting at the end of the house farthest from the door, the operator pours the formaldehyde into the containers with the permanganate as he moves toward the door, and leaves the house or room at once, closing and sealing it. The reverse of this precedure, dropping the permanganate into the containers containing the formaldehyde, is sometimes the easiest method.

SULPHUR FUMIGATION

In sulphur fumigation, a good grade of flowers of sulphur should be used at the rate of 5 or 6 pounds per 1,000 cubic feet of air space to be fumigated. It is most commonly burned in pans or metal trays with the edges high enough to prevent the molten sulphur from flowing over the edge and setting fire to the house, or in oil drums cut in half lengthwise. A little excelsior or crumpled paper is placed along the bottom of four or five pans, and the sulphur is poured along each side of it. Some growers prefer to use less sulphur per pan, covering the bottom of each tray with an inch layer of excelsior and sifting the sulphur over this. Still another method is to put excelsior in the bottom of the container and over this to place a piece of coarse screen, cover the screen with a piece of newspaper, and pour the sulphur upon this. The use of a larger pan containing water, into which the smaller one containing the sulphur is placed, is an effective aid in preventing fire and accidents. In the case of houses having dirt floors, pits may be dug therein and the sulphur burned as in the pans. *Sulphur should not be burned upon concrete floors, as the heat is likely to cause the concrete to crack and buckle, thus throwing the burning sulphur about and setting fire to the house.*

In any method the important thing is to get as complete combustion in as short a time as possible. Recent experiments have shown that it is very unusual to get complete combustion by any method of

burning sulphur within the houses, and that the time required for burning averages about 3 hours. In burning sulphur within the houses a uniform concentration is rarely if ever obtained, as the hot sulphur dioxide gas from the pans rises to the top of the house. By the time the gas has cooled sufficiently to settle to the floor the total concentration of sulphur dioxide gas within the house has reached a point too low to be of much value. There is also considerable hazard of fire in burning sulphur within the houses by the methods now commonly used.

AN EFFECTIVE DEVICE FOR BURNING SULPHUR

The use of the sulphur burner described below has been found by experimentation to be an improvement over the methods now in com-

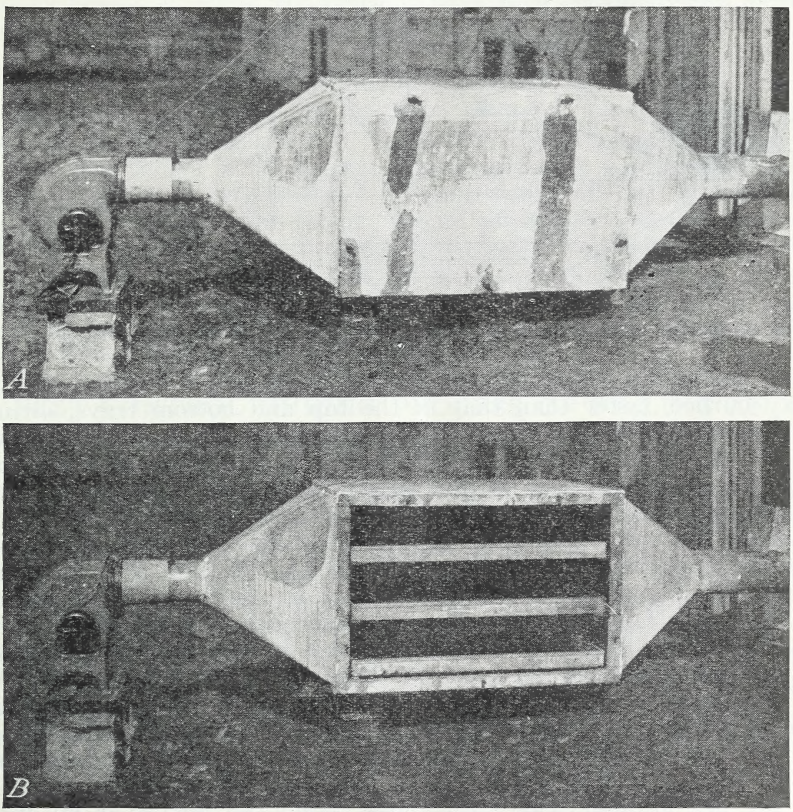

FIGURE 1.—*A*, Outside sulphur burner in operation, with door closed and fan connected; *B*, outside sulphur burner with door open to show arrangement of pans.

mon use for fumigating mushroom houses with sulphur. It produces a highly concentrated gas in the house with less than one-third of the quantity of sulphur required by the pan method, burns the sulphur completely within about 30 minutes, reduces the fire hazard, and gives completely uniform distribution of the gas within the house. The details of construction are shown in figures 1 and 2.

The apparatus consists of a rectangular box 2 feet square and 3 feet long, of 18-gage galvanized sheet iron on a frame of 1½-inch angle iron. At each end is a cone 18 inches long, terminating in an open pipe, the intake pipe being 5 inches and the outlet pipe 6 inches in diameter. Within the box, sliding upon supports of 1½-inch angle iron riveted to the frame, are three trays, each 23 by 34½ by 2 inches, and each capable of holding about 15 pounds of sulphur. The sides of the trays are strengthened by pieces of 1½-inch strap iron, and a piece of the same material is run from these crosswise beneath the center of each pan to prevent sagging. The door at the side is secured by bolts and wing nuts. To prevent the gas from escaping, a gasket of asbestos cloth is placed between the door and the body of the burner. All seams and connections are strongly crimped or riveted, as the heat of the burning sulphur will quickly melt any solder work.

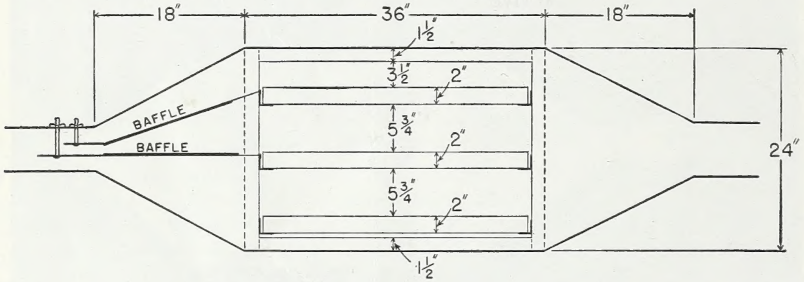

FIGURE 2.—Diagram showing details of construction of the sulphur burner.

In preliminary tests it was found that the sulphur in the middle tray burned faster than that in the top and bottom trays, owing to uneven distribution of air. This condition was corrected by baffles in the intake funnel. The baffles are of 18-gage galvanized sheet iron cut to fit the intake cone, with a piece of three thirty-seconds by 1¼-inch strap iron riveted to the center of each, longitudinally. The ends of the strap iron are pierced with holes and project into the intake pipe, being held in place by bolts, the nuts of which are outside, on top of the intake pipe (fig. 2), to allow adjustment of the baffles. The bases of the baffles rest upon the tray supports. The spacing of the baffles must be determined by testing, or by the use of an anemometer, so that each pan receives air at the same rate.

The fan used is of the centrifugal type in a steel housing, connected directly to a one-twentieth horsepower electric motor running at 1,750 revolutions per minute, and with a horizontal 5-inch discharge and 6-inch single suction. This fan delivers 150 cubic feet of air per minute. Since the outlet from the burner is an inch greater in diameter than the intake, there is practically free delivery of air. In use, the fan is connected to the intake, and stovepipe is led from the delivery pipe into the house through an asbestos-lined opening in a false door made of wallboard. It is advisable to extend the outlet, by means of several extra lengths of stovepipe, so that the delivery of gas will be along the floor in the cen-

tral alleyway. This gives slightly better distribution of gas and also muzzles any flame that might otherwise be forced into the house.

The fumes from the sulphur have not caused appreciable corrosion of the galvanized metal, of which the greater part of the burner is composed, during 2 years that it has been in use. The iron frame has corroded to a slight extent, but the burner will probably last for a long time under ordinary conditions.

The burner was designed to burn 32 pounds of flowers of sulphur, this being the maximum dosage allowable in a standard mushroom house of 16,000 cubic feet when at peak heat. With this dosage, flame has at times been blown into the house through 10 feet or more of pipe. When using the maximum dosage it has therefore been thought best to cut down the speed of the fan by attaching one or two electric-light bulbs to the line or by using a rheostat. In empty houses excellent fumigations have been obtained with as little as 20 pounds of flowers of sulphur.

HEAT STERILIZATION

In small spaces and where facilities are available, heat alone may be used for the eradication of mushroom pests before the house is filled. The source of the heat may be steam, or it may be electricity if the current is very cheap. A temperature of 120° to 125° F., if maintained for a few hours, should effectively rid the room of all insect and mite pests. A 16-inch electric fan with the blades directed upward at an angle of 45° should be kept running during this time to distribute the air evenly, otherwise the top of the space will be very hot and the air for a few inches above the floor will not be hot enough to kill the insects and mites.

PEST CONTROL DURING PROCESS OF FILLING AND HEATING OF BEDS

When compost is placed in the beds a secondary fermentation occurs and the temperature starts to rise. A small quantity of manure in a large cool place will not heat up so well as a greater quantity, nor will it raise the temperature of the surrounding space greatly. If the filling occupies too much time, considerable heat is wasted. For this reason the house should be filled as quickly as possible, the aisles swept out and cleaned of all loose manure, and the doors closed tightly. Some growers fill a part of the house and wait several days before filling the remainder. If manure is scarce, it is better to form storage heaps until a sufficient quantity is obtained to fill the house in one operation.

NATURAL AND ARTIFICIAL HEATING

It is most important that a good heat be obtained in the compost at the time the house is filled because heat is the mushroom growers' cheapest and best method of combating insects and other closely

related pests, as well as being necessary to "sweat out" the manure and put it in the best condition for the spawn to "run." An ideal condition is to have the bottom beds at a temperature above 120° F. and the top beds below 140°. At these temperatures all forms of insect and mite pests will either be killed or driven to the surface of the beds, where they can be reached with fumigants.

Since ground beds are very difficult to heat properly, the insect and mite pests contained therein cannot be driven to the surface or killed by heat, and, since the fumigants in use at present do not penetrate the compost more than an inch or so, the pests present in such locations will survive and reinfest the house. Consequently, if the ground beds cannot be raised 4 or 6 inches from the floor to allow circulation of heated air beneath, it is better to abandon them entirely. The temperature of the bottom beds will usually lag about 10° behind that of the top ones, and air temperature will usually be 15° or 20° less on the floor than under the ceiling.

If the weather is very cool at the time of filling, or, as is frequently the case in amateur mushroom culture, the quantity of manure is too small and the insulation insufficient to allow the temperature to rise, the house may be heated artificially. Where steam or hot-water heat is not available, kerosene or oil burners have been used with success, but the use of oil heaters should usually be avoided, as oil fumes sometimes have a harmful effect upon mushroom growth. Care must be taken that the beds do not dry out too much while this is being done.

Because the lower beds are filled first and lose much of their latent heat, and also because the warm air naturally rises to the top of the house, the top beds heat faster and attain a higher temperature than the bottom ones. A more even distribution of heat may be obtained by the use of some method of forced air circulation. Where electric current is available the best method is to place two or three 16-inch electric fans in the central alleyway. Most growers place the fans upon the floor of the house along the center of the house, adjusted in such a manner that the air current is directed upward at an angle of from 45° to 80°. Better results, however, have been obtained by placing the fans on supports resting upon the top beds, with the air current directed straight down. By this means the heated air in the top of the house is driven to the floor and is forced to circulate over the bottom beds before again rising to the top of the house. When the top beds have reached a temperature ranging from 120° to 130° F. the fans should be started, run for 5 or 6 hours, shut off to cool for 2 or 3 hours, and then run for another 5 or 6 hours.

To keep a check upon the conditions during the heating process, accurate thermometers should be inserted into the top and bottom beds and hung in the central alleyway at the top and bottom of the house. Judging from preliminary results of experiments now being conducted, it seems fairly safe to state that an air temperature ranging from 120° to 125° F., if maintained for a few hours, and if evenly distributed through the room, will kill all insects and mites harmful to mushrooms. Such temperatures on the floor of the house and just above the floor are difficult to maintain, consequently fumiga-

tion is necessary. The manure in the beds will reach a much higher temperature during this time but should not be allowed to exceed 145°. A temperature of 120° for 48 hours will eradicate the "bubble" disease (mycogone) also.

During the heating of the compost in the beds much moisture is driven off. In basements of dwellings it is inadvisable to try to reach a high temperature unless the room can be sealed tightly enough to prevent the moisture and heat from warping the floor above.

FUMIGATION

When the temperature of the beds has reached its maximum the house should be fumigated with either sulphur or cyanide before the spawn is placed in them.

SULPHUR

Sulphur should be burned at the rate of 1½ to 2 pounds per 1,000 cubic feet of air space. The amount used per 1,000 cubic feet, however, should not exceed 2 pounds. Within 5 or 6 hours after the sulphur has finished burning the ventilators should be opened, the house allowed to air out, and then closed again to prevent too rapid cooling. Owing to the slow rate of burning and the rapid absorption of gas by the moisture in the house, it is doubtful if an efficient fumigation is ever attained by burning sulphur in pans within the house at peak heat. The outside burner previously described (p. 5) will give much better results.

Sulphur fumigation has a tendency to raise the acidity of the first one-half inch or so of the beds (the limit of penetration of the gas), and a green mold often follows. This soon disappears, however, and neither it nor the increased acidity of the surface of the beds seems to have any harmful effect upon subsequent mushroom growth.

When a house to be fumigated is immediately adjacent to another in production, every precaution should be taken that the fumes do not reach and damage the growing mushrooms. The ventilators of the house in bearing should be open, and the house in heat should be fumigated only when there is no wind, or when the wind is blowing away from the house in bearing. In case of a double house, the other half of which is in bearing or spawned, it is better to use cyanide rather than to risk damage from sulphur fumes.

HYDROCYANIC ACID GAS

The three materials in common use for hydrocyanic acid gas fumigation are calcium cyanide, sodium cyanide and sulphuric acid, and liquid hydrocyanic acid.

Since the application of liquid hydrocyanic acid requires special equipment, as well as special training on the part of the operator, and since it gives little better results than calcium cyanide or sodium cyanide and acid, it may be left out of this discussion.

The use of calcium cyanide at the rate of 1 pound per 1,000 cubic feet of air space is at present the most common method for fumi-

gating mushroom houses at peak heat. As hydrocyanic acid gas is readily absorbed by moisture, the house, although damp, should not be wet, with puddles of water standing in the alleyways, or much of the gas will be lost before it is fairly liberated. Experiments have shown that the maximum concentration of gas is reached in from 10 to 20 minutes after the cyanide is scattered. *In view of the deadly nature and the rapid evolution of this gas, every precaution should be taken against accidents.* In the case of a single house, the chemical should be scattered in the central alleyway as evenly and quickly as possible, beginning at the back of the house and working toward the door. Special care should be taken that the alleyway is clear of obstructions before the fumigation is begun, as a stumble over some obstacle while walking backward and scattering the cyanide might easily result fatally. In the case of a double house the material is scattered in the two main alleyways, the workers starting together at the far end and working toward the doors, timing themselves so as to reach the doors simultaneously. After the operators have left the house the doors should be closed and tightly sealed and left so for about 12 hours.

Caution: When entering a house after fumigation, use a gas mask until the house has been thoroughly aired out.

The same precautions are necessary as with sulphur to prevent fumes from reaching and damaging growing mushrooms, although this gas is not so harmful to them as sulphur fumes. In the case of a double house, the other half of which is in bearing, the doors between them should be made gastight, all cracks and openings in the partition tightly sealed, and the doors and ventilators of the house in bearing opened. As a further precaution, it is desirable to fumigate when the wind is blowing away from the house in bearing.

The so-called pot method of fumigation, in which sodium cyanide and sulphuric acid are used, is almost as easy and convenient as that with calcium cyanide, and gives a more rapid liberation of gas and a much higher concentration. The material should be used at the rate of not less than 8 ounces of sodium cyanide to 12 fluid ounces of a good grade (66° B.) of commercial sulphuric acid and 16 fluid ounces of water per 1,000 cubic feet of air space. Three or four 3-gallon glazed crocks may be used for generators. The necessary quantity of water is measured out and divided among these. They are then set at equal intervals in the central alleyway of the house. The acid is similarly measured out and the necessary quantity placed in a glass jar beside each generator. The sodium cyanide having been similarly weighed out (it can be obtained in ½-ounce or 1-ounce "eggs" to save this work), and the proper quantity for each jar having been put into a heavy brown paper bag (the thickness of paper may be doubled for additional safety by using two bags, one inside the other, for each charge), the operator takes the twisted necks of the bags in his left hand, enters the house, and pours the acid into each generator as he reaches it. Having reached the back of the house, he then walks rapidly toward the door, placing one of the bags of cyanide in each generator as he passes it. The acid requires a short time to eat through the paper bags, and the

operator is usually well outside the door before the first charge begins to generate gas.

As the floor is always the coolest part of a house that is heating or at peak heat, it is here that insects and mites are most likely to survive the heat. With any method of fumigation it is therefore desirable that as much of the gas as possible be kept in the lower part of the house. Unless fans are kept running in the house at the time of fumigation, the gas, being hot as well as lighter than air, will rise to the top of the house. The best results have been obtained by raising the fans to the level of the fourth or fifth beds, about 5 or 6 feet or more from the floor. In the case of the pot method the air blast from the fans should be directed straight down over each generator. This causes the gas to blow along the floor and between the lower beds. After 20 or 25 minutes the concentration becomes nearly uniform throughout the house, but for the first 20 minutes most of the gas is along the floor where it is most needed. Unless fans are of the fully enclosed type, it is better to wait for about 10 minutes before turning them on, as there is a remote possibility of gas and air forming an explosive mixture which might be set off by a spark. In experimental fumigation of commercial mushroom houses it was demonstrated, by using chemically equivalent dosages of calcium cyanide and sodium cyanide with acid (1:1½:2), that sodium cyanide and acid was much superior to calcium cyanide in the concentration of gas obtained and was about half as expensive per fumigation.

Sodium cyanide is extremely poisonous, and great care should be exercised in handling it. It should be stored under lock and key where it is not accessible to children or careless persons. The same precautionary measures should be taken with the acid.

The same rules as to procedure and safety apply to fumigation at peak heat in cellars or other small spaces as apply during preparation for the crop. Hydrocyanic acid gas should not be used in or adjacent to dwellings at all, and sulphur only when there is no possibility of the fumes escaping. In these places it is better to depend upon heat for mushroom-pest control at any time when the beds do not contain spawn.

GENERAL SANITARY MEASURES

After the house has been through the "heat" and has been properly fumigated, precaution should be taken to prevent reinfestation by insects and the other closely related pests mentioned previously. Doors and ventilators may be made fly-tight with cheesecloth, or, better, 30-mesh copper screen, if it is found possible to do so without interfering too much with ventilation. This prevents the entrance of flies and also of any mushroom mites that they may be carrying.

Control of individual species of pests is discussed under separate headings.

In passing from a house infested with mushroom pests to one not so infested, great care should be taken that no insects are carried on the person or clothing.

All stem butts and discarded mushrooms should be carried away and burned, or placed in a hole, then covered with quicklime or kerosene and a layer of earth. They should never be allowed to stand about the house.

When the house has finished bearing and is about to be cleaned out, it should be allowed to dry out thoroughly and be fumigated if possible. In any case, the spent compost should be hauled to some distance from the houses and spread out thinly over the soil so that the weather may destroy as many of the pests as possible.

CONTROL OF MUSHROOM PESTS IN BEARING HOUSES

After the beds have been cased, the temperature should be kept rather low. For the best results it should be possible to maintain an air temperature ranging from 50° to 55° F. A temperature below 55° F. is more to be desired than one above that level, as the lower temperature seems to be favorable for mushroom growth and is low enough to retard materially the development of insect and other pests of mushrooms.

The purpose of the treatments and practices recommended in the preceding sections is to prevent the infestation of beds. To date no entirely satisfactory methods have been devised for the control of insects and mites in the beds after the beds have been spawned. The majority of the chemicals used for this purpose either do not penetrate the beds deeply enough or they have a harmful effect upon the spawn, which is very easily damaged.

PRINCIPAL PESTS ATTACKING MUSHROOMS AND METHODS FOR THEIR CONTROL

Pests in mushroom plantings may be roughly divided into four groups: Flies, mites, springtails, and miscellaneous.

FLIES

All things considered, mushroom flies seem to be the most destructive insects attacking the mushroom crop. The injury consists of the feeding of the maggots upon the spawn in the beds and the tunneling into the stems and caps of the mushrooms, rendering them unfit for use. No direct damage is done by the adult flies, but the indirect damage they cause in transporting mites and disease organisms from bed to bed and from house to house, while difficult to estimate, seems to be nearly if not quite as important.[2]

Flies attacking cultivated mushrooms are of three general kinds, known as mushroom flies or fungus gnats, manure flies, and gall gnats.

MUSHROOM FLIES OR FUNGUS GNATS

There are at least four species of sciarid flies (of the genus *Sciara*) that have been recorded as injuring cultivated mushrooms seriously in the United States. Probably the most common of these is *S. pauciseta* Felt. Others that have been noted as attacking mush-

[2] CHARLES, VERA K., and POPENOE, C. H. SOME MUSHROOM DISEASES AND THEIR CARRIERS. U. S. Dept. Agr. Circ. 27, 9 pp., illus. 1928.

rooms are *S. coprophila* Lintner, *S. multiseta* Felt, and *S. agraria* Felt. They are much alike in appearance, habits, and life history, and for practical purposes may be regarded as one species. Figure 3, *C*, shows a drawing of an adult fly. Sciarid flies are slender, with rather long legs and antennae. They usually carry their wings folded flat upon the back when walking or at rest. In color they are black or yellow black. The males have a pair of claspers at the apex of the abdomen.

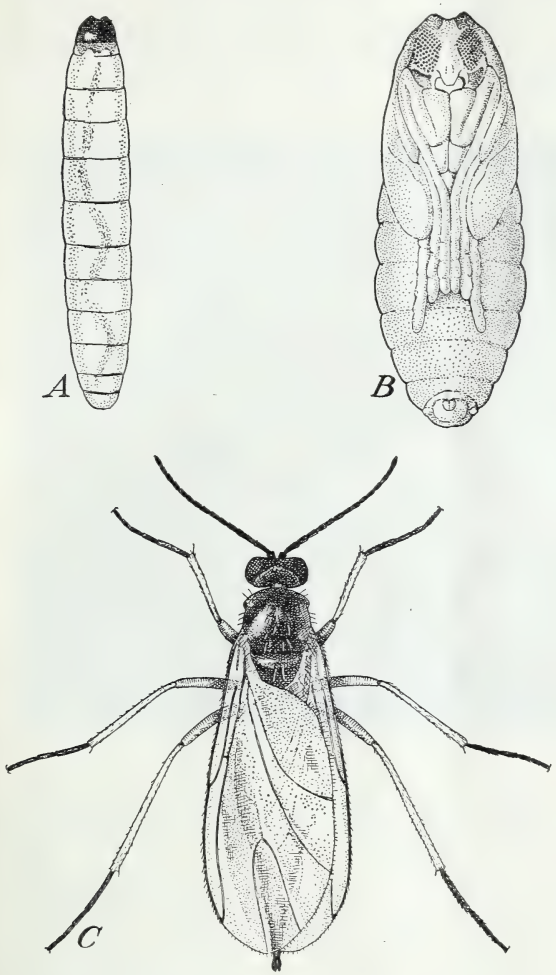

FIGURE 3.—Stages of a mushroom fly, *Sciara pauciseta: A*, larva, × 10; *B*, pupa, ventral view, × 15; *C*, adult, × 12.

The eggs (fig. 4) of these flies are very small, oval, white or yellowish. They are laid in the compost or spawn, in cracks in the casing soil, or upon the mushrooms. Under favorable conditions of temperature and humidity the egg hatches in 4 or 5 days into a legless white larva, or maggot, with a shiny blackhead (fig. 3, *A*). After feeding for from 10 to 14 days the larva approaches the surface and spins a fragile silken cocoon, in which it transforms into a pupa (fig. 3, *B*). In 5 or 6 days the adult fly emerges, and it is capable of mating within a few hours. Females may commence oviposition within 24 hours. As each female is capable of laying from 200 to 300 eggs, and there is very little natural mortality among the larvae, it will be realized that the potential rate of increase is very great.

No effective method of combating the maggots of these flies within the beds is known. Control must be had through reducing the number of adult flies, thus decreasing the number of eggs laid. Traps and insecticides are the principal means of killing the adult flies.

TRAPS

Traps are of many varieties, but they all depend upon light to attract the flies to them. They have been used with success, but they should be considered merely supplementary and not be depended upon to the exclusion of dusting. The simplest type of trap is a pane of glass set into the south or east end of the house, usually in the door, about a foot or more above the floor. Fly paper or sticky tree-banding material is placed about this to catch the flies as they come to the light, or a pan containing a little kerosene may be placed

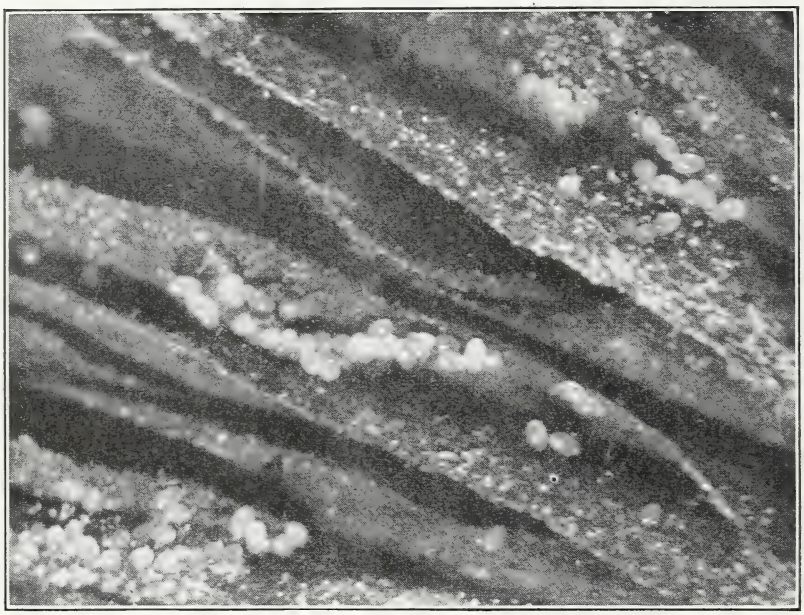

FIGURE 4.—Eggs of mushroom fly, *Sciara pauciseta*, × 16.

beneath it, into which the flies will fall and be killed. The pane of glass should not be too large, as the ends of the beds will then be too well illuminated and the female flies will often oviposit before they go to the glass, or they will not be attracted to the glass at all. Experiments have shown that a glass pane of 72 square inches or less is most satisfactory for attracting flies to daylight.

Another type of trap is one in which the flies are attracted by an electric light, drawn in by a fan, and retained in a bag or jar. A trap of this type, used experimentally in a very heavily infested house, caught over 187,000 flies in one 24-hour period, of which 75 percent were females, and more than half of these had not laid all their eggs. As in the case of traps depending upon daylight to attract the flies, the illumination should not be too intense. A 40-watt white-frosted electric-light bulb has given most satisfactory results. If either the daylight or the artificial light used as a lure is not intense enough the flies will not be attracted in great numbers, and if it is too intense they seem to be satisfied before they actually reach the trap and do not come any nearer to it.

INSECTICIDAL DUSTS

There are a number of insecticidal dust mixtures on the market that are used for mushroom fly control. A dust composed of 60 percent of pyrethrum, with 40 percent of finely ground diatomaceous earth or clay as a carrier, has been found satisfactory. The commercially prepared dusts vary in composition, but are usually based on this pyrethrum-carrier mixture, sometimes with other substances added. It is desirable to get as fine a dust as possible so that it will remain suspended in the air for a long time, and it is also well to get as light-colored a dust as possible, since darker dusts sometimes settle upon the mushrooms and render them unsightly, thus decreasing their market value.

The house should be watched carefully, and as soon as a few flies appear it should be treated with the dust at the rate of 2 or 3 ounces per 1,000 cubic feet of air space. The majority of the growers dust two or three times a week. Before dusting, the temperature of the house should be allowed to reach 60° F. or more, then the dust should be applied, and the house should be left closed overnight. At any lower temperature the flies are less active and the dust more inert. A good fan-type duster should be used and the dust thoroughly distributed throughout the house. If a duster is not available a good distribution of the dust may be obtained by shaking the dust slowly out of a bag into the air blast from an ordinary electric fan directed toward the ceiling of the house.

FUMIGANTS

Fumigation with calcium cyanide, at the rate of 1½ to 2 ounces per 1,000 cubic feet, has proved successful against adult flies if carefully used, but is said to retard the growth of mushrooms if the fumigation is repeated more than four or five times. If this fumigant is used, it is best to use it between "flushes." In preparation for this fumigation the beds should be allowed to dry out for 2 days or so, all salable mushrooms picked off, and the temperature allowed to rise to at least 60° F. The house should then be fumigated and left tightly closed for several hours. The aisles should be damp, but not wet, when the calcium cyanide is spread upon them.

MANURE FLIES

At least three species of phorid flies (of the genus *Megaselia*) have been reported as doing commercial damage in mushroom plantings. These are *M. albidihalteris* Felt, *M. agarici* Lintner, and *M. iroquoiana* Malloch. As in the case of the mushroom flies, these three species of manure flies are so nearly alike in appearance and in their biology that they may be regarded as one species when their control is considered. They are frequently seen in immense numbers about the compost heaps and on the exterior of the houses. The adult flies (fig. 5) are black or blackish in color and usually slightly smaller than the sciarid flies. They are much more compactly built, the legs are stouter and not so long, and the head is rather small and the thorax large, giving them a hump-backed appearance. They are quite active, moving about constantly in a series of jerky runs.

The life history of these flies is known only in a general way. The time required by the various stages is dependent upon conditions of temperature, humidity, and food, as is the case with the mushroom flies.

The eggs are very minute, white, and elongate-oval, and are laid in the compost or casing soil. They hatch in about 6 days, under usual mushroom-house conditions. The larvae, or maggots, are shining white or yellowish, about one-fourth inch long when fully matured, legless, and without head capsules. After feeding for 10 days or more the maggots stop feeding and transform into yellowish pupae, appearing almost like small seeds. From these, after another interval, the adult flies emerge.

The infestation of mushroom beds by manure flies usually results from the introduction of larvae with compost that afterwards does not get sufficiently heated to kill them, or from eggs laid by adults that get into the house immediately after the heating. The damage is done by the larvae and is about the same as that described previously for the sciarid larvae, except that since the infestation by these pests occurs early in the development of the beds, the spawn may be prevented from running out from the spawn pieces, or the pieces themselves destroyed. The larvae also attack the growing mushrooms more readily than the sciarid larvae. The greater part of the damage is done early in the season, usually becoming less noticeable after the beds are producing, although during the warm weather at the end of the spring crop much damage may be done to both spawn and growing mushrooms.

FIGURE 5.—An adult manure fly, *Megaselia albidihalteris*, × 18. (Popenoe.)

Control of manure flies (Phoridae) is about the same as for mushroom flies (Sciaridae), except that dusts must be used more liberally, the phorid flies being more resistant to control measures.

By light watering and proper temperature, especially in the early flushes, it is possible to force mushroom growth ahead of the development of the fly maggots, thus producing a crop in spite of the infestation. If dusting to control the adult flies is begun early, all of the eggs will have been laid within a short time, and oviposition reduced to a minimum thereafter. When the maggots in the beds have pupated, the spawn is free to grow without further interference.

GALL GNATS

The adult gall gnats are small, delicate flies, brownish in color with orange abdomen. The species most common at Arlington Experiment Farm, Va., has been determined as *Mycophila fungicola* Felt. They are very inconspicuous, as they remain flat against the bedboards and usually fly only when disturbed. The larvae are

bright yellow or orange, one-fourth inch or less in length. At times these may appear in large numbers upon the casing soil and mushrooms, and if sufficiently numerous may cause injury to the spawn, and to the mushrooms by eating small holes into the stems and caps. Normally, however, these flies are minor pests of mushrooms. The control measures given for mushroom and manure flies should be effective against these flies also.

MITES

Four species of mites are important pests of mushrooms, one very serious, two less so, and the fourth sporadic and of minor importance.

THE MUSHROOM MITE

The mushroom mite (*Tyroglyphus* sp.) (fig. 6) frequently occurs in enormous numbers in mushroom plantings and is capable of completely ruining the crop. The initial infestation may be the result of introduction of some stage of the mites into the house with the compost, or upon the clothing of workers or other persons entering the houses, or upon the bodies of various species of flies coming from infested houses.

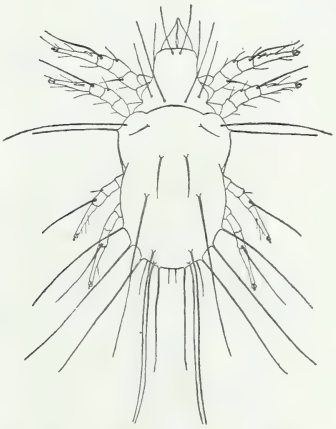

FIGURE 6.—Adult of a mushroom mite, *Tyroglyphus longior* Gerv., × 100.

This mite damages mushrooms by eating holes into their caps and stems in the button stage, preventing them from developing or rendering them unmarketable, and in eating the mycelial threads in the spawn. If these mites become very numerous they may consume all of the spawn and may then feed upon the manure itself, reducing it practically to a mass of fine frass. Mites feed in all except the egg and hypopial stages. Being so small, mites in the mushroom beds are often overlooked. Unless they are very numerous the damage to the mushrooms may be slight, and the damage to the spawn is reflected only in smaller yield, which may often be attributed by the grower to other causes.

The eggs are extremely small, although rather large as compared to the parent mite. They are oval, white or yellowish, and are laid in the spawn or casing soil, or upon the mushrooms. In from 8 to 14 days the egg hatches into a very small, white, six-legged larva. In another 8 or 10 days the larva molts and becomes a nymph. The nymph is a little larger than the larva and has eight legs instead of six. After a longer period of feeding and after undergoing two more molts the nymph becomes an adult mite.

At times a migrating stage or condition occurs between two of the nymphal molts, known as the hypopus. In the hypopial stage the mite is flattened, with eight legs, rudimentary mouth parts, and an area of suckers upon the ventral side. Not every individual passes through this stage, and the conditions under which it is formed are not well understood. Although unable to feed, the

hypopus can survive for a long time under adverse conditions. It will grasp and cling to any moving object with which it comes into contact, and is capable of being carried about by flies and gamasid mites, and upon the clothing of workers in the mushroom houses. Flies have been seen that were so covered with mites in the hypopial stage that they were unable to fly. When the hypopus drops or is brushed off, it continues its development into an adult mite if it finds conditions favorable.

Prevention of infestation by the mushroom mite is the only certain means of avoiding damage to the crop. It is important that the beds go through a good heat, as the mites are nearly always present in the manure and can be controlled most effectively by killing them at this time. Control by chemicals has been attempted, but in most cases has not been successful, or only partially so.

THE LONG-LEGGED MITE

The long-legged mite (*Linopodes antennaepes* Banks) (fig. 7) is less abundant than the mushroom mite. It is extremely difficult to control. In some places it occurs sporadically, while in others, although nearly always present, it is said to do little damage. Since it is native to this country, occurring normally under leaves and boards on the ground out of doors, it may be brought into nearly any mushroom house, and if proper conditions are present it may develop into a serious pest. The body is very minute, yellow to reddish brown in color, and the legs, especially the front pair, are very long and slender.

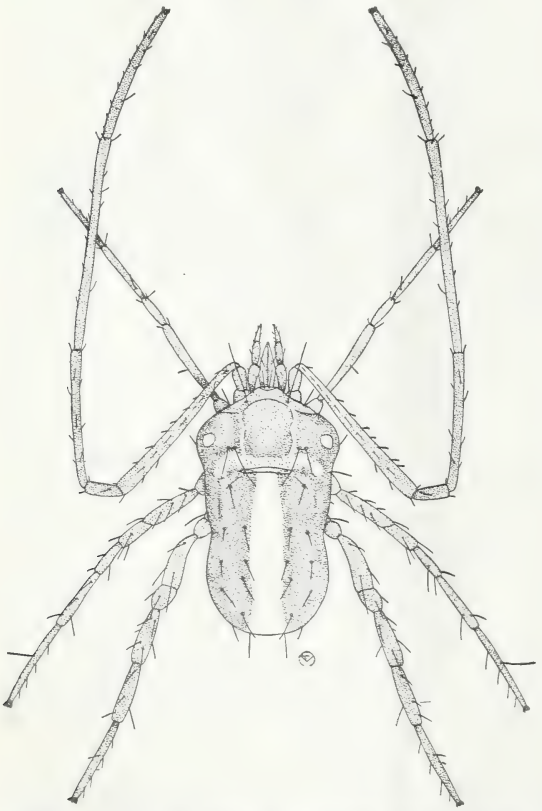

FIGURE 7.—The long-legged mite (*Linopodes antennaepes*), × 70.

Very little is known of the life history of this mite. The minute round eggs are laid in groups in the casing soil and hatch in about 8 or 10 days into very small white larvae. These molt in 6 or 8 days into nymphs, with longer front legs than the preceding stage. These mites have never been observed damaging spawn, and

several attempts to rear them beyond the first nymphal stage upon spawn have been unsuccessful, so it is probable that the activities of this species are almost entirely confined to the surface of the mushroom beds. They damage mushrooms by chewing off the feeder roots of the growing mushrooms, causing the stems to constrict at the base, and injuring or killing the developing mushroom.

Sanitation and prevention of infestation are the best methods of avoiding damage by these mites. The mites are easily killed by heat, having been found to succumb to 100.4° F. for one-half hour at a relative humidity of 89 percent. If the temperature along the floor does not reach this height, however, the mites in that location will recover and reinfest the beds. They are very active and are capable of crawling into cracks in the floor and walls to escape the heat.

Since these mites are found chiefly on or near the surface of the beds, the control measures recommended for the mushroom mite should be effective against them.

In addition to the two mites mentioned above, *Rhizoglyphus phylloxerae* Riley and *Histiostoma* sp. have occasionally been noted as attacking mushrooms. The control methods used against the other species of mites would probably be equally effective against these two species.

SPRINGTAILS

Springtails are, in general, very small, gray, blackish, or brown insects, ranging from about one sixty-fourth to one-sixteenth of an inch in length. Beneath the abdomen of each insect there is a powerful springlike appendage which, when released, is capable of hurling the insect through the air for a distance many times its own length. In a wild state springtails live normally in damp places beneath rubbish and leaves, and most of them feed upon fungi. It is probable that any of these "wild species", when once introduced into the mushroom houses, might prove to be serious pests. A number of species of springtails are found frequently in mushroom beds. These include *Achorutes armatus* Nic., *Priostoma minuta* Tull., *P. simplex* Fols., *Entomobrya* sp., *Xenylla welchi* Fols., *X. humicola* (O. Fab.) Tull., *Lepidocyrtus albicans* Reut., *L. cyaneus* Tull., *L. cyaneus* var. *cinereus* Fols., and *L. lanuginosus* (Gmel.). All of these are capable of doing damage to spawn and mushrooms throughout the season. Two of these springtails are shown in figure 8, *A* and *B*.

Some growers have the idea that the presence of springtails in the houses is to be desired; in other words, that springtails in numbers are an indication of a good crop. This is possibly true to the extent that conditions favorable to springtails also favor the growth of mushrooms, but it is also true that these same favorable conditions may allow the springtails to multiply fast enough to reduce the crop materially. Springtails inflict damage by eating the spawn and by chewing holes in the stems and caps of the mushrooms. These pests are so easily overlooked that the grower frequently attributes the reduction in yield to some other cause.

The life history of these creatures is very simple. The minute spherical eggs are laid in groups in the compost or spawn. They hatch in about 10 days into minute replicas of the adults except for

their lighter color. After a period of growth and several molts, these become capable of reproduction. Almost from the moment they hatch from the egg they are capable of feeding upon and damaging spawn and mushrooms.

Springtails are usually brought into the houses with the compost, but may enter later through cracks. For this reason it is important that the surroundings of the mushroom houses be clean and free from rubbish so as to offer as little refuge as possible to these pests. Although they are capable of withstanding intense cold, they are easily killed by heat. In the case of *Lepidocyrtus lanuginosus*, a springtail found doing damage in commercial houses in Ohio, it has been determined that heating infested mushroom houses to a temperature of approximately 104° F. for 10 minutes will kill the majority, if not all, of them. For this reason it is important that the houses go through a good heat, and that the bottom beds and floor be also well heated. Otherwise springtails escaping from the upper beds will survive upon the floor and bottom beds and later reinfest the entire house.

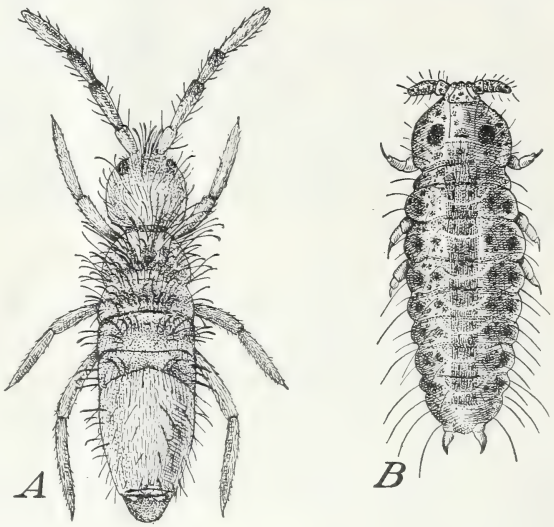

FIGURE 8.—Two species of springtails that attack mushrooms: *A*, *Lepidocyrtus lanuginosus*, × 30; *B*, *Achorutes armatus*, × 60.

As in the case of the mushroom mite, springtails in the beds are very difficult to control, since insecticides do not penetrate the beds well, so only the insects upon the surface are killed. Sometimes, by lightly spraying the beds with water 4 or 5 hours before treatment, the springtails may be brought to the surface, and more of them killed by subsequent applications of insecticides.

Fumigation with calcium cyanide at the rate of 2 to 2½ ounces per 1,000 cubic feet of air space is also fairly effective.

Some species of springtails have a habit of congregating in mushroom houses at certain times in enormous numbers, looking like piles of gray powder in the aisles. Whenever springtails are found congregating in the aisles of a house they should be swept up and burned or otherwise destroyed.

MISCELLANEOUS PESTS

A small mycetophagid beetle, *Litargus balteatus* Lec., has become a pest, during the last 2 years, in at least two mushroom establishments in the West. Very little is known of this insect or of methods for controlling it.

The meal moth (*Pyralis farinalis* L.) was found feeding in the spawn upon one occasion. The adults may be controlled by pyrethrum dust mixtures and probably would never be of importance in houses that are dusted regularly for fly control.

Sowbugs, also known as "pillbugs" and "wood lice", are elongate, convex, slate-gray crustaceans, with seven pairs of legs. Fully grown specimens may be one-half inch in length. They occasionally become numerous enough in mushroom beds to cause some damage by eating holes in the buttons and in the caps of matured mushrooms. In a cellar or other small area it is possible to control sowbugs by hand-picking them off the beds. Where they congregate in clusters along the edges of the beds, hot water may be poured upon them. Pyrethrum dusts as used for the mushroom flies will give some control if they actually come in contact with the sowbugs. In using dusts, the beds should be allowed to dry slightly, and should not be watered for approximately 24 hours after application of the insecticide. Light fumigations with calcium cyanide when the sowbugs are feeding on the surface of the beds (usually at night) are said to be effective. Poisoned baits are also effective against these creatures, but their use in mushroom houses cannot be recommended because of the danger of accidentally getting poison on the mushrooms.

Slugs seldom become numerous enough to be of importance, but where they do, hand-picking is the most effective remedy.

Crickets sometimes become pests in mushroom beds by eating holes in the caps. They are not difficult to discover and can be collected by hand-picking methods and destroyed.

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